
# 4th Annual PPS Arctic Meeting

## 14-17 April 2009
## Volkovo village, Zvenigorod, Russia

**Contents:**

## Organising Committee, Faculty of Geography, Moscow State University

Academician Nikolay Kasimov, Dean of the Faculty of Geography, Head of the Organising Committee

Prof Sergey Dobrolyubov, Deputy Dean of the Faculty of Geography, Deputy Head of the Organising Committee

Prof Andrey Kapitsa, Head of the Department of Environmental Management

Prof Alexander Berlyant, Head of the Department of Cartography and Geoinformatics

Prof Yuriy Knizhnikov, Head of the Laboratory of Aerospace Methods, Department of Cartography and Geoinformatics

Prof Elena Golubeva, Deputy Head of the Department of Environmental Management, Executive Secretary of the Local Organising Committee

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Info from Olga

PPS Arctic

**Preliminary Agenda**

# 4th Annual PPS Arctic Meeting

**14-17 April 2009**
**Volkovo village, Zvenigorod, Russia**

| **Tuesday, 14 April** | | |
|---|---|---|
| Arrival to Moscow | | |
| 16:00 | Coach from MSU to Universitetsky conference centre, Volkovo village near Zvenigorod (travel time 1-1.5 hours) | |
| | Registration | |
| 19:00 | Welcome Dinner | |

| **Wednesday, 15 April** | | |
|---|---|---|
| 08:00 | Breakfast | |
| 09:00 | Andrey Kapitsa, Olga Tutubalina and Elena Golubeva | Welcome from Moscow State University |
| 09:10 | Annika Hofgaard | Welcome to the 4th Annual PPS Arctic Meeting |
| | | Aim of the meeting and brief update on PPS Arctic |
| ***Short updates by national groups/projects - Chair: A. Hofgaard*** | | |
| 09:30 | Olga Tutubalina | Natural science activities within Benefits/Russia |
| 09:40 | Gareth Rees | UK group activities, progress and results |
| 09:50 | Brian Starzomski | PPS Arctic Canada activities, progress and results |
| 10:00 | Tatiana Vlasova | PPS Arctic social science activities and collaborations |
| 10:10 | Annika Hofgaard | PPS Arctic Norway activities, progress and results |
| 10:20 | **Coffee/Tea and poster set up** | |
| ***Scientific program - Chair A. Hofgaard*** | | |
| 10:50 | David Hik | ***Invited overview presentation:*** The role of snow in structuring the forest-shrub-tundra ecotones: upscaling in subarctic mountains |
| 11:20 | Catherine Plasse and Serge Payette | A biogeographical analysis of the distribution and colonization of frost hollows along a latitudinal gradient |

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|---|---|---|
| 11:40 | Ingrid E. Mathisen and Annika Hofgaard | Climate growth relationship in *Pinus sylvestris* along coast-inland gradients |
| 12:00 | Joannie Savard and Serge Payette | Vegetation Dynamics on Alpine Summits in the Boreal Forest (Quebec, Canada) |
| 12:20 | Natalia Lukina et al. | Plant- induced variability in soil nutritional status in the forest –tundra ecotone on the Kola peninsula |
| 12:40 | Brian Starzomski | The relationship between bird communities and vegetation across a treeline ecotone in the Mealy Mountains, Labrador, Canada |
| 13:00 | **Lunch** | |
| 14:00 | Mélissa Vachon | Migratory caribou activity in the vicinity of the hydroelectric reservoirs of La Grande Complex, James Bay, Subarctic Quebec |
| 14:20 | Tatiana Vlasova et al. | Socially-oriented observations in coupled human-nature system investigations in the Russian North within IPY PPS Arctic. |
| 14:40 | Andrey Medvedev | Organization and visualization of spatial information for northern socially-oriented observations |
| 15:00 | Poster Session | |
| 15:30 | **Coffee/Tea** | |
| 16:00 | Poster Session continued | |
| 17:00 | Topic-specific Group meetings | |

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|---|---|
| 19:00 | Dinner |

| **Thursday, 16 April** | | |
|---|---|---|
| ***Scientific program continued - Chair G. Rees*** | | |
| 08:00 | Breakfast | |
| 08:30 | Gareth Rees | Remote sensing activities in PPS Arctic |
| 08:40 | Gareth Rees et al. | Position and dynamics of the circumarctic forest boundary from coarse-resolution satellite imagery |
| 09:00 | Hans Tømmervik et al. | The dynamics of the forest lines (birch and pine) in northern Norway and Kola Peninsula (Russia) revealed by spectral unmixing of multi-temporal satellite images in the period 1972 – 2007. |
| 09:20 | Olga Tutubalina et al. | An approach for mapping micro-mosaic structure of plant cover through integrating field data and high resolution images of the forest –tundra ecotone in the Kola Peninsula |
| 09:40 | Mikhail Zimin et al | Using information from geoportals for mapping the northern forest line boundary |
| 10:00 | **Coffee/Tea** | |

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|---|---|---|
| 10:20 | Anna Mikheeva et al. | 50 years of treeline change in Khibiny mountains |
| 10:40 | Valentina Kravtsova, Alexandra Loshkareva | Changes of forest-tundra vegetation distribution in Kanentiavr key site (Kola Peninsula) since 1960 |
| 11:00 | David Hik et al. | Patterns of treeline change in the southwest Yukon |
| 11:20 | Ekatrina Shipigina, Gareth Rees | Remote Sensing of Human Impact on the Position and Structure of the Northern Treeline |
| 11:40 | Zaika Yu., Vikulina M. | Climate and snow precipitation in central Kola Peninsula. |
| 12:00 | **Lunch** | |
| 13:00 | Poster Session | |
| 14:00 | Topic-specific Group meetings | |
| 15:00 | **Coffee/Tea** | |
| 15:30 | Rees/Hofgaard | Presented papers & Joint publications |
| 15:40 | All | General discussion |
| 16:30 | Annika Hofgaard | PPS Arctic and the future |

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| 19:00 | ***Conference Dinner*** |

## Friday, 17 April

***Excursion and transport to Moscow***

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| 08:00 | Breakfast |
| 10:00 | Coach to Savvino-Storozhevsky Monastery in Zvenigorod for excursion |
| 13:00 | Lunch in Zvenigorod |
| 14:00 | Coach leaves to Moscow, to bring participants to hotel(s) near MSU |
| 15:30 | Arrival to Moscow, check into hotel |
| 16:30 | Informal excursion to the Red Square lead by Moscow team members |
| Evening | Dinner, Moscow city centre |

## Saturday, 18 April

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| 11:00 | Extra excursion and sightseeing in the city centre (e.g. to Tretiakov Picture Gallery, can be lead by Moscow team members ) |

# Participants

4th Annual PPS Arctic Meeting
Volkovo village, Zvenigorod, Russia, 15-17 March, 2009

| | | |
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# Abstracts

4th Annual PPS Arctic Meeting
Volkovo village, Zvenigorod, Russia, 15-17 March, 2009

## Tree recruitment at and beyond the treeline - potential for tree cover change in Northern Norway and North-Western Russia

**Sigrun Aune[1] and Annika Hofgaard[2]**
[1] *Norwegian University of Science and Technology, N-7491 Trondheim, Norway*
[2] *Norwegian Institute for Nature Research, Trondheim, Norway*

The transition from forest to tundra form an important ecological ecotone, and its location and structure is predominantly influenced by climate. Thus, tree occurrence in the ecotone is expected to show rapid increase in growth and recruitment in response to the climate warming. However, whether this has occurred in response to last decade's climate warming of the North-western European region can be questioned and calls for in depth studies. The aim of this study is thus to evaluate potential for rapid tree encroachment in low-arctic tundra through age structure analyses of the current birch treeline and the birch recruitment beyond the treeline along climatic gradients in northern Norway and Kola Peninsula. The study analyses the both the history of the current treeline location and the potential for changes along coast-inland gradients in the north and along the gradient of decreasing impact of Atlantic air masses from west to east in the study region (in total six areas). In each area, one north facing mountain slope was selected, along which 20 mountain birch (*Betula pubescens* Ehrh. subsp. *tortuosa* (Ledeb.) Nyman) treeline trees were cored at ground level and at 2 m for determination of age, recruitment year, and time required for reaching tree size. Further, all birch seedlings/saplings in 20 m wide sampling bands stretching from the treeline and 100 altitudinal meters into the alpine tundra above the treeline were sampled. In one area lacking altitudinal gradient the sampling bands stretched 350 m from the treeline into the arctic tundra. Field data collection was don according to the PPS Arctic Manual, and in addition to age, the following variables were recorded for all sampled tree and sapling individuals: height, stem diameter at ground level and breast height (1.3 m), crown diameter, vitality, ground moisture conditions, plant community and GPS position. 120 treeline trees and 618 saplings were sampled and aged in 2007 and 2008, and preliminary results point towards deviating response pattern among climate regions. Three areas, the western inland and the central coast and inland, show non-overlapping age distributions between trees and saplings. These populations are characterized by old treeline trees and young saplings, established mainly after 1990. The areas are summer grazing grounds of reindeer and sheep and the structure indicates an herbivory-linked high turnover at the

sapling stage. The lack of recent recruitment among treeline trees points towards a rather stable or retreating treeline location in these areas with no likely advance in the near future. The western coastal area and the eastern inland (central Kola Peninsula) area show overlapping tree- and sapling ages and abundant recruitment of saplings with potential to reach tree size in the near future. In particular, the central Kola Peninsula area shows a recent change in treeline (established during the last 40 years). The presence of many saplings with a height of 0.5-1.95 m beyond the treeline indicates a potential for a considerable further relocation of the treeline in this area, and in the western coastal area under current environmental conditions. The coastal easternmost site, characterized by its flat transition to the arctic tundra, differs from the other areas both in age- and height structure; characterized by a total overlap in age among trees and saplings, and a random height distribution of saplings in relation to distance from treeline. This area show characteristic of a stationary treeline with few individuals established during last three decades. The collected data will be further analysed for pattern and importance of environmental variables corresponding to tree and sapling positions along the gradients by the use of PCA/RDA and correlation analysis.

## Climatic and edaphic constraints on tree growth across an altitudinal gradient, Mealy Mountains, central Labrador, Canada.

**Sarah Chan[1], Elizabeth Sutton[1, 2], and John D. Jacobs[1]**
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Within highland areas of the boreal forest region, the altitudinal limit and number density of *trees* (erect forms of tree species), e.g. *Picea glauca, P. mariana, Abies balsamea*, and *Larix laricina*), are determined by a number of biotic and abiotic factors. As part of an interdisciplinary project of the International Polar Year, IPY-PPSA, we have undertaken a study of the abiotic factors that are associated with plant associations across an altitudinal gradient at a long-term study site in central Labrador. The objectives of this study are to determine the range of climatic and edaphic conditions existing along an altitudinal gradient across a subarctic-alpine treeline and to assess which factors are likely to be limiting for tree growth above present tree line.
In the Mealy Mountains, Labrador, an altitudinal gradient of three automated climate stations has been recording climatological parameters for 8 years. These recordings have allowed an assessment of the different climatic conditions from closed canopy forest through the forest-tundra transition zone to the uppermost habitat of sub-arctic tundra, an altitudinal gradient of over 400 m. At the upper limit of the open canopy forest, the average number of growing degree days (GDD) for the period is 676, the station at the treeline limit has 664 GDD, and the tundra site has an average of 420 GDD. Mean growing season temperatures from the lowest to highest climate stations are, respectively, 7.6ºC, 7.3ºC and 4.6ºC. Also, our short-term record also shows a positive trend of increasing growing season temperatures.

The soils study involved plant-root-simulator (PRS) probes for nutrient analysis, bulk samples, soil moisture and temperature measurements, measurement of the organic layer depth, and description of soil profiles across forest-transition and tundra habitats. No significant differences were found in the macronutrients N, P and the elements S and A, whereas differences in Ca, Mg, K, and Mn are significant ($p < 0.001$) and show lowest levels in the tundra sites. Since all three zones have similar levels of the main nutrients N and P, it is likely that available nutrients are not limiting for tree species in any of the zones, including the Tundra. Organic layer thickness was significantly thicker in the Tundra zone than in the Forest-transition.

## Patterns of treeline change in the southwest Yukon

**Ryan Danby[1, 2] and David Hik[2]**

[1] *Department of Geography and School of Environmental Studies, Queen's University, Kingston, Ontario, Canada*
[2] *Department of Biological Sciences, University of Alberta, Edmonton, Alberta, Canada*

The mountains of southwest Yukon provide a useful analogue for the changes in biodiversity expected to continue across the circumpolar north. Field studies to-date and some preliminary modelling suggest a significant potential for change, particularly with respect to an advance of trees and shrubs. This potential advance indicates that continued climate warming would result in the loss of habitat for alpine obligates as alpine vegetation types are reduced to smaller areas upslope. However, the upslope shift of vegetation types will be mediated by the availability of suitable substrate as well as changes in other climate-related variables, especially snow cover. Ongoing work is directed at providing better information about the rate of change and potential effects on the entire ecosystem.

## Filling in the gaps: Spatial patterns of trees within the forest-tundra ecotone

**Danielle L. DeFields**
*School for Resource and Environmental Studies, Dalhousie University*

Background: Arctic and subarctic treelines are predicted to change in response to climate warming through both a northern migration of trees into tundra habitat and an increase in tree density. Characterizing the spatial patterns of trees can provide insight into the processes that act on forest-tundra ecotones and how this transition may respond to future environmental change.
Questions: At what distances are adult and juvenile trees characterized by aggregated, regular or random spatial patterns within the open canopy of the forest-tundra ecotone? At what distances is there a spatial dependence between adult and juvenile trees? Do spatial patterns vary with aspect, between or within sites?

Location: Altitudinal treelines across Canada. White spruce (*Picea glauca*) dominated forest in the Ruby Ranges, Yukon, Canada (61.19˚ N / 138.35˚ W) and larch (*Larix laricina*) forest in the Mealy Mountains, Labrador, Canada (53.62˚N / 58.84˚W).
Methods: Trees were mapped in 30 m x 30 m plots. First-order characteristics of marked point patterns were analysed using nearest-neighbour analysis. Second-order characteristics were characterized by univariate and bivariate neighbourhood density function statistics.
Results and Conclusions: In the Mealy Mountains, all plots showed little departure from complete spatial randomness. Clustering of all age classes occurs at 0.5m and 5.5m in some plots. Bivariate analyses indicate positive spatial association between adult and juvenile trees at 0.5m from the adult tree. The small scale positive spatial interactions between size classes found in some plots suggest facilitation between adult and juvenile trees. In the Yukon, both juvenile and adult trees display regular spatial patterns. Bivariate analyses indicate a negative spatial association between adult and juvenile trees at small scales on both slopes. In contrast to Labrador, the forest-tundra transition in the Yukon appears to be regulated by competition instead of facilitation between size classes, at most distance scales. The spatial arrangement of trees at both sites is influenced by various processes and physical site attributes, resulting in different patterns of change.

## Position and dynamics of the circumarctic forest boundary from coarse-resolution satellite imagery

**Kelly Dolan and Gareth Rees**
*Scott Polar Research Institute, Cambridge, UK*

Satellite remote sensing, especially from instruments having wide spatial coverage and high temporal resolution, provides a unique possibility to obtain a consistent synoptic view of the tundra-taiga ecotone. Satellite imagery with a spatial resolution in the range 0.25-1 km and a swath width of around 2000 km has been collected systematically since around 1980 and is appropriate to this task. Amongst other instruments of this type, the Advanced Very High Resolution Radiometer (AVHRR) has been operational in various versions since the late 1970s, while the somewhat more advanced Moderate-Resolution Imaging Spectrometer (MODIS) has been operational since the late 1990s. In addition to the basic data product of at-satellite radiance, a number of derived products have been or are being generated from both instruments. These include, inter alia, normalised difference vegetation index (NDVI), surface albedo and vegetation continuous fields (VCFs). The NDVI is simply a mathematical transformation of the ratio of the at-surface reflectances in near infrared and red wavebands, known, at least at temperate latitudes, to be strongly correlated with the above-ground biomass represented by green leaves. The VCF is a statistical estimate of the proportion of each pixel occupied occupied by trees. In this paper we describe an investigation of the scope of these derived products to give consistent agreement with other definitions of the position of the treeline, and hence (with appropriate intersensor calibration) to identify changes the position of the treeline over the last few decades.

## Scots pine radial growth responses to climate variability and change since the Little Ice Age, northern Norway and Kola Peninsula

**S. Dovärn[1], A. Hofgaard[2], L. Söderström[1] and B. Ø. Solberg[3]**
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[2] *Norwegian Institute for Nature Research 7485 Trondheim, Norway*
[3] *The Directorate for Nature Management 7485 Trondheim Norway*

The past provides useful and essential information to deduce forest-tundra ecotone responses to climate change. In this context, comparison of Scots pine radial growth along major environmental gradients is a helpful tool. The aim of this MSc project within PPS Arctic Norway is to analyze how radial growth of Scots pine (*Pinus sylvestris*) in different climate regions of its northern distribution limit has responded to climate variability and change during the last 130 years. The study use three different climatic regions of northern Europe for the analyses: western Northern Norway; central Northern Norway, and Eastern Northern Norway and Kola Peninsula. Two sites per region represent inland and coastal conditions, respectively. Standard dendrochronological procedures are used in the analyses and data is standardised to emphasise high frequency variation. Residual chronologies were used in the response-, principal component- and correlation analyses. Data from the eastern area will be analysed in autumn 2009. Preliminary results from the western and central regions show that: *i)* High July temperature and low July precipitation are the most important monthly climatic variables among all sites; *ii)* Correlation to summer temperature showed a deviating low level for the western inland site during the first half of the 20th century; decreasing trend in 1970's for all sites except the western coastal site; and during the most recent decade the correlation has decreased to a common low for all sites (all time low for all except the western inland site); and *iii)* High February temperatures has negative effect on growth in coastal areas, and May precipitation has positive effect on growth in the site with the coldest winters. Decreasing correlation with climate variables is a common trend in the northern hemisphere and the reason is under debate among dendroecologists. Further analyses of the data are needed but a general conclusion is that there have been great changes in growth response through the studied period with periodically deviating response pattern among climate regions.

## Socially-oriented observations in the Kolguev Island.

**Peter M. Glazov**
*Institute of geography, Russian Academy of Science, Moscow, Russia*

We chose the Kolguev Island for our socially-oriented observations and research as present economic, ecological and demographic situations on it are typical for many regions of the Extreme North. Main issues influencing people's quality of life are: northern delivery, a problem of small indigenous peoples of the Extreme North, a problem of transport and communication connections and many others. Works in compliance with the project were started in 2007 and have been continued in 2008. Questioning and interviewing of inhabitants allowed us to make social characteristic of the Bugrino village. Six observers from

local people are carrying out observations by the prepared and sent by us questionnaires. Data collection by the phenological questionnaire is carried out annually since 2005. During questioning on the basic problems of the life quality, most important issues were identified: lack of workplaces, bad housing conditions, low wages, insufficient food supply and low transport accessibility. These data coincide with our concept, which was developed during some years of our work on the island. Because of the biological value of the island for the waterfowl population status we carried out detailed researches on traditional use of nature resources of local population. Anonymous questioning of hunters was conducted on specially devised questionnaires. We estimated present harvesting of game birds species on the island. As the result of our studying of the traditional use of natural resources the scheme of territorial division of the island on three basic zones (hydrocarbon resources extraction zone, a zone of reindeer breeding and hunting and fishing of local people zone) were made. We estimated the change of nature use, in connection with change of biodiversity that is probably connected with changes of a climate and population dynamics. Crisis in spiritually cultural sphere of local people in the Bugrino village is observed. Cultural degradation greatly affects other aspects of life of the island population and it is typical for the majority of the northern regions of Russia. All works were conducted in compliance with the program “ECORA”, “PPS ARCTIC-BENEFITS”, “IPY 2007-2008”.

## Pine re-vegetation of sandy shores at Tersky coast of the White Sea, Kola Peninsula

**Elena Golubeva and Elena Glukhova**
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Area of Research. Our study took place at the Terskiy coast of the White Sea (southern Kola Peninsula, Russia). More than 20 thousand hectares of sands which are subject to erosive processes are present at the coasts of the White Sea. Constant processes of movement of sands by wind form small hillocks. One of largest sand hills is located in the mouth of the Varzuga River at Terskiy coast, and is known as Kuzomenkie sands with area over 2.2 thousand hectares. This “desert” was formed because of adverse natural factors and economic activities: cattle breeding, wood cutting and forest fires. Sands advanced towards a channel of the Varzuga River and have changed hydrological regime in its mouth. In 1980 replanting of trees at the Varzuga River coast has been started to stabilize the coast. Pinus sylvestris L. Lapponica was chosen as the basic tree species. Also Juniperus sibirica Burgsd, Betula pubescens Ehrn and Leumus arenaris (L) Hochst. were planted to promote higher acclimatization of plants.
As a result more than 60 hectares of plantings have been created and they have established well, at present forming 15 -20 year old pine forests. The aim of our research is the assessment of these pine forests established in desert seaside ecosystems at Terskiy coast of the White Sea.
Objects and methods of research. Study of structure and morphometric parameters of pine plantings was conducted in 2004 - 2007 in test areas 20x20 м in size for forests of four different ages: plantings of 1985, 1990, 1995, 2000. In each area geobotanical descriptions were made and morphometric characteristics of the trees growing in groups and of single

trees were described. The following parameters were measured: height of trees, diameter of trunk at root and at height of 1.3 m, annual linear growth of trunk and age of needles. Diversity of species has been also estimated. In total data for 500 trees were statistically analyzed.
Results. The height of trees varied from 0.5 up to 3.5 meters. At all test areas height of the trees growing in groups exceeded height of single trees in all years of planting. Significant differences in height of the trees growing in group and separately appear when they reach 10 years of age.
Diameter of trunks at root varied from 1 up to 9.1 cm. For trees growing in a group diameter of their trunk at root is more than for separately standing trees of the same age. This distinction becomes significant when trees reach 15 years of age.
The annual linear growth of trees trunks measured in 2006 varied from 13.1 up to 24 cm. The linear growth of a trunk increases with age. In plantings of 2000 it was 13.1 cm, and in plantings of 1985 it was 24 cm. The most appreciable distinctions are characteristic for plantings older than 10 years.
The age of needles changes from 1 year to 4 years. For young plantings (of the year 2000) the age of needles on average is 1 year. For adult plantings the life of needles increases considerably. The age of needles for the trees growing in groups is almost 2 times more than for single trees.
Specific biodiversity increases from 3 species in plantings of 2000 up to 6 species in plantings of 1985. Rumex acetosa and Thymus L. prevail among the new species in young plantings.
In adult plantings, Empetrum nigrum, Vaccinium uliginosum, Vaccinium vitis-idaea, and Calluna vulgaris are present, i.e. plants typical for northern pine woods. Thus our research results demonstrate high efficiency of pine plantings on sands, presenting opportunities for solving the problem of erosion development by these methods for the entire Terskiy coast.

## Changes of mountain forest-tundra ecotone near Monchegorsk, central Kola Peninsula, due to industrial impact

**Elena Golubeva, Maria Golubeva, Anatoly Krasnushkin, and Pavel Blyumberg**
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The technogenic factor influences vegetation structure changes, dynamics of bioclimatic zone boundaries and elevational belts, including altitudinal and northern treeline. Therefore we have selected the area impacted by *Severonickel* smelter in Monchegorsk to assess technogenic treeline changes in central Kola Peninsula.

Sample profiles were chosen across several uplands of the Monchetundra mountain ridge, which are nearby the smelter. There are: the southern peak of the main Monchetundra ridge; the eastern spur of the main ridge (Mt. Nittis) and lower hills of Sopcha and Nyud. The sample profiles run through selected sites on opposite slopes of each upland and consist of several reference plots. Each reference plot was photographed, geolocated with a hand-held GPS, geobotanical descriptions were carried out, and soil samples were collected for express analysis of pollutant metals.

The research demonstrated that on all studied hillslopes natural alternation of elevational belts is observed. However, almost in all instances the vegetation of elevational

belts is degraded. The original natural ecosystems can often be only identified from dried tree remains and damaged shrub vegetation. The most acute situation is present nearby the smelter, where the vegetation cover is almost destroyed on the northern and eastern slopes of Sopcha, on the northern and eastern slopes of Nittis, as well as on the eastern slope of main Monchetundra ridge. We can see partial recovery of vegetation on the southern and south-western slopes of Sopcha, on the western slope of Nyud, as well as on the southern slope of Nittis. Western slopes, which are facing away from of the smelter, are the least susceptible to contamination.

The results of geochemical analysis show soil catastrophic contamination near the factory, with substantial excess of the Maximum Allowable Concentrations (MAC) for all researched metals (Ni, Cu, Pb, Zn, Fe). For the Monchetundra ridge, the lowest metal content has been recorded in the tundra zone on the western slope. The highest metal content is observed in the forest belt on the eastern slope of Monchetundra, facing towards Severonickel. Similar wind- and terrain-dependent distribution of pollutants is observed for the other hills.

Geobotanical description data testify to significant reduction in species diversity for all of the area of research, as well as reduction of the total vegetation coverage. The floristic similarity index for the contemporary vegetation cover and that in the pre-industral era (the 1930s) calculated according to the Sorensen - Chekanovsky formula has the lowest value in the forest belt of Monchetundra and Nyud slopes, facing towards to the smelter. Slightly higher values are found for the herb tundra belt on both slopes of Nyud, on the eastern slope of Monchetundra and on the western slope of Nittis, as well as in the birch shrub belt on both slopes of Nyud and on the eastern slope of Monchetundra. The highest value of the index is found for belt of the low-shrub tundra and for the birch shrub belt on the western slopes of Nittis, Monchetundra and Nyud.

It is practically impossible to discuss the natural dynamics of vegetation belts, because the technogenic factor influence on the structure of ecosystems is too high.

## Causes and consequences of change at treeline: Preliminary results from the International Polar Year project PPS ARCTIC CANADA

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PPS Arctic Canada (Present processes, Past changes, Spatio-temporal variability in the Arctic delimitation zone, Canada) is the Canadian component of PPS Arctic. In the summers of 2007 and 2008, we collected data at over a dozen locations in the Yukon, Northwest Territories, Nunavut, northern Manitoba, northern Quebec and Labrador. The results from these studies will contribute to our short-term objectives: 1) an analysis of recent change in tree and shrub distributions, 2) the collection of environmental and microclimate data to accompany treeline change, 3) an investigation of the mechanisms of vegetation change at treeline, 4) the mapping of the spatial pattern of tree and non-tree species at treeline and in tundra islands within the boreal forest to predict future changes as treeline migrates, 5) an assessment of the role of disturbance, and 6) the development of models of the long-term relationship between environmental change, resource availability and human health and

well-being in the forest-tundra ecotone. We have made considerable progress including collecting excellent data, conducting experimental and observational studies, training students and actively engaging northern communities. This poster presents some of our early results including detectable changes including treeline advancement and a reduction in permafrost. Our research is important for Canada, especially northerners, since it will show and predict the effects of treeline migration on northern ecosystems and communities.

## Ecological factors controlling conifer distribution at the boreal-arctic transition in Labrador, Canada

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As climate warms, boreal conifers are expected to expand their elevational and northward ranges; ecological factors will influence the extent of this expansion at the regional scale. In the forest-tundra transition zone of Mealy Mountains (Labrador, Canada), we expect that limits on the production of viable seeds will create a bottleneck to conifer (*Picea mariana, P. glauca, Abies balsamea, Larix laricina*) range expansion while moss and lichen seedbeds and dwarf shrubs will facilitate early survival, and recruitment of seedling/saplings will require disturbance events which will be driven by gap dynamics. Seed production and dispersal is the primary means of range expansion in conifers. Greater than 90% of pollen grains produced by conifers are viable, but limited growing degree-days resulted in <10% viable seeds. Predispersal seed predation by cone insects destroys the majority of filled seeds of all species. Seedbed type facilitates early conifer survival ($1^{st}$-year survival: un-vegetated plots: 56%; natural seedbeds: 81%). As seedlings grow past the groundcover layer, dwarf shrubs become facilitators with lower mortality (2007 survival: open tundra 75%, shrub nurse 69%; 2008 survival: open tundra 42%, shrub nurse 46%). Herbivory accounts for 20-50% of 1st-year mortality. In the closed-canopy forest, exposed mineral soil associated with windthrows appears to be the most significant factor limiting seedling establishment. As a result of small-scale gap disturbances, we expected multicohort stands but a lack of observed seedling/sapling regeneration leads us to suggest that vegetative reproduction contributes to stand age-structure. Temperatures in Labrador are predicted to increase by 2°C by 2090. As temperature increases, seed limitation may decrease, facilitative shrubs and moss seedbeds are expected to expand their range. Disturbance is expected to increase in scale and frequency. Knowledge of these processes will be important inputs in a biogeographical model predicting vegetation response to climate change.

## The role of snow in structuring the forest-shrub-tundra ecotones: upscaling in subarctic mountains

**David Hik**
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A rapid shift in arctic and alpine plant community distribution, composition and structure is likely as species respond to climate change. The cumulative evidence suggests that the phenology and extent of seasonal snowcover has a critical role in determining changes in ecotone position and that a better understanding of snow is necessary to integrate physical, ecological and atmospheric processes at treeline and shrubline. Such analyses are severely hindered by the poor resolution of snowcover data. I will provide an overview of some recent experimental studies, analysis of remote sensing data and modeling efforts to better integrate the role of snow in determining the structure of arctic and alpine ecotones at different scales, focusing on the southwest Yukon.

## Human Experience Of Cryospheric Change In Nunavut, Canada: Preliminary Findings

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There is a significant consensus within both scientific and northern communities: dramatic change is occurring in the Arctic (e.g. ACIA 2005, Hinzman 2005, Duerden 2004) and the transformation of the cryosphere itself provides a critical focal point for research contributing to our understanding of health and wellbeing. Despite debates about the relative importance of drivers of change (e.g. Zalasiewicz et al., 2008), the occurrence of environmental change, both gradual and rapid, is not at issue (although many elements of landscape processes and impacts still require further study). The necessity of adaptation at all scales of both human organization and landscape dynamics is not in dispute either. However, in moving forward from identification of processes of environmental change to definition of impacts, then to development of strategies for mitigation and adaptation, we enter stormy and contested regions. Why? Because integration of physical and social science perspectives, along with those of actors who engage locally, regionally, nationally and internationally with realities of a changing cryosphere, is necessary in order to build effective policy and to set priorities for mitigation and for adaptation. In reaching for multiparty consensus on actions, we face limitations of knowledge, of knowledge interoperability, and of decision-making processes; as well as potentially conflicting goals and objectives, priorities and visions. Lack of agreement and co-operation can affect both capacities for communication and adaptation as well as resources available for mitigation. Standard approaches to decision-making in the south and the north see government agencies consulting with stakeholder representatives, usually at a point after an issue has been defined and after measures available to address it have already been scoped, but before a final decision is taken. This process is also a reflection of past practice with respect to knowledge creation and assumes that community and other “local” interests are farther

removed from expert knowledge. Here, by positioning local or traditional knowledge as complementary source, in conjunction with social and physical sciences in current research, we are building transdisciplinary knowledge (Wilcox, 2008), as a starting point for multi-party consensus around environmental change in Nunavut, Canada and for inclusive strategies for mitigation and adaptation, emphasizing local communities and their concerns.

*Preliminary Findings:* Practically, we integrate physical and social science of northern environmental change by situating our research at the nexus of environment, health and well being, as framed by northerners themselves, in a series of specific studies constructed to include both research and design elements in methods of enquiry. We report briefly on 5 related studies currently under investigation: 1) food choice among women and men, and thus impacting health and well being, 2) local perceptions and understanding of ecological changes linked to a changing cryosphere through investigation of spatial and temporal variation in observations of plants and as interpreted from photographs; 3) design choices in arctic architecture as represented by a healing centre, directly contributing to health and well being; 4) integration of data from these sub-studies, and refinement of mixed methods for advancing transdisciplinary work, as steps in the iterative research process; and 5) development of protocols modeled on Canadian standards for ethical and just research involving humans that yield both point in time images ("snapshots") of social, environmental and economic conditions, as well as in-depth profiles at selected sites. The purpose of this research is to understand adaptation, mitigation and community resilience, in the face of cryospheric environmental change, using mixed methods to achieve social-ecological systems integration.

In Nunavut, Canada, we are documenting food choice among women and men. Previously Donaldson investigated factors influencing food choice. Results here indicated that multiple factors are involved both in food choices and in travelling and hunting decisions. We note that uncertainty plays a larger role: for example, the thickness, extent and stability of sea ice in the Cape Dorset area have changed in recent years, making it increasingly difficult to travel and hunt; and weather patterns have also changed. Local residents have been responding and coping to environmental changes primarily by adapting their subsistence hunting practices. These findings are consistent with Reidlinger and Berkes (2001) earlier work in the Western Arctic, and suggest that adaptation to rapid cryological change is occurring in the Foxe Basin, off Baffin Island, as well.

During preliminary site visits to Sanikiluaq, Rankin Inlet and Baker Lake in 2007, other community observations and reports of impacts confirmed the regional nature of change. While the form of environmental expression varied, the reports all pointed to systemic change.

We find these "social observations" to be an extremely sensitive detector of environmental change. The challenge is then to communicate these findings so that they can be integrated with studies that model change on global or regional scales. If synergies among multiple factors across scales are in fact the case, as the regional variability of the warming trends suggest, then strategies for adaption and mitigation must be capable of recognizing and addressing local and regional factors implicated in these changes. Additionally, linking the data generated by physical environmental studies with social impacts requires social data. The fine-grained "social observations" approach may contribute most significantly here. We anticipate additional data on this question from the second project "plants and photographs through time", which provides a direct link to daily life,

focusing spatial and temporal observations of plants, and using photographs to derive anecdotal information.

In terms of proactive adaptation through design, the third study, investigating appropriate architecture, offers a critical view of past practice and resulting increases in risk associated with cryospheric change. Next steps will address incorporation of community values in design of a healing centre. The fourth project is iterative, and will integrate results from the other studies as they become available. The fifth project to develop protocols for social, environmental and economic observations is well underway, with a consultation meeting scheduled in April 2008.

## Tree layer structure in forest – tundra ecotone in the Kola Peninsula

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The forest belt of Khibiny Mountains is mainly formed by spruce (*Picea obovata*), pine (*Pinus sylvestris*) often forms secondary stands originated from fires and cuttings. Both species representatives could be found at tree line Climate changes due to warming and wetting effects could result in an upward expansion of trees. The main goal of this study was to characterize contribution of different tree species to tree layer in forest-tundra ecotone in Khibiny Mountains. This study was carried out for 5 strips of 10 x 50 m in Um'echorr. Number, diameter and height of trees, saplings and seedlings were measured on plots with areas of 500 $m^2$. Forest belt in study area was presented by secondary pine forest originated from fire event about 50 years ago. Type of forest is *Pinetun cladinoso-fruticulosum*. Number of living pine trees was 70 (dead trees- 7), living saplings – 118 (dead saplings- 12), and seedlings- 17. Spruce and birch contributed insignificantly (2 spruce saplings and 2 seedlings and 10 birch saplings per 500 $m^2$). Average diameter of living pine trees was 8 cm, height - 6,1 m. (dead – 12,4cm and 8,5 m correspondingly). In tree layer of transition zone between forest and forest tundra pine is the predominant tree but spruce contributed more significantly. Type of forest is *Pinetum cladinoso-hylocomioso-friticulosum*. Number of living pine trees was 33, saplings - 10 and seedlings – 2. Number of living spruce trees is 12, saplings - 38, seedlings – 17. Average diameter of pine trees is 7.6 cm, height- 4.5 m, diameter of spruce is 7.7 cm, height – 5.9 m. Number of birch trees was 30, and saplings – 33 per. Because of active regeneration of spruce, it is reasonably to suggest that spruce forest will be developed here. Forest-tundra communities in the study area were dominated by pine. Number of living pine trees and seedlings were only 7 and 2 whereas number of saplings was 88. Contribution of spruce and birch was insignificant. In transition zone between forest- tundra and tundra no trees have been found, number of pine saplings was 5, number of pine and spruce seedlings was comparable (2). In lichen tundra, ecosystems 2 pine and 4 birch saplings on plot with area of 500 $m^2$ have been found. Phytomass and productivity of different fractions of pine trees (needles, branches, stem, bark, roots) have been calculated with the application of allometric equation $\log y = a + b \log d^2h$. The coefficients *a* and *b* in these equations have been determined earlier for pine trees in Khibiny mountains.

According to plans for field works of 2009, to get more accurate information about number of trees, saplings and seedlings, the area of plots will be extended.

## Vegetation micro-mosaic structure mapping in the forest-tundra ecotone on the Kola Peninsula

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Vegetation cover in forest-tundra ecotones is a mosaic. To assess the micro- mosaic structure of vegetation cover in forest, forest-tundra and tundra, very large scale mapping of micro-groups consisting of combinations of different plant species can be carried out. It allows us to assess the structural diversity of vegetation cover, the contribution of different micro-groups to plant communities in forest-tundra ecotones, and to make conclusions about dynamics of vegetation cover when tree line is changing.

Field mapping of vegetation micro-mosaic structures has been carried out for 13 strips of 10 x 50 m at the scale of 1:20 in three key areas: Um'echorr and Tuliok in Khibiny mountains and Kanentiavr to the east and west of Lake Kanentiavr in northern Kola Peninsula. The strips were divided on squares 1 x 1 m, and plant micro-groups were drawn on millimetre paper. The borders of micro-groups were identified accordingly the distribution of the predominant plant species.

About 50 microgroups below and between the crowns of different trees have been identified in forest-tundra ecotones at three sites under investigation. The calculation of area of micro-groups is in progress.

## Changes of forest-tundra vegetation distribution in Kanentiavr key site (Kola Peninsula) since 1960

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Changes in boundaries and character of forest-tundra transition zone at Kola Peninsula have been investigated through remotely-sensed images at the example of Kanentiavr key site, 40x40 km in area; its center locates at 68° 50' N, 34° 30' E (55 km to the east from Murmansk and 45 km south of Barents Sea shore). Terrain of key site is a socle plain built of horizontal strata, with denudated hills (up to 300-350 m) and lakes in tectonic faults.

The key site includes parts of 3 natural zones: forest, forest-tundra, tundra, each of them have complex structure with various share of forest, shrub and tundra vegetation. The northern tree line (of birch) is found within the forest-tundra ecotone, but cannot be discerned in the imagery available (resolution from about 1 meter to 15 meters). Two

important boundaries can be however marked using the remotely-sensed imagery: the northern forest line and the southern limit of the dwarf shrub - lichen tundra.

Analyses of vegetation cover changes were made for 2 periods with various changes of climatic conditions: 1960-1985 and 1985-2004. Meteorological data (Murmansk and Teriberka stations) show the absence of trend in mean annual temperatures and precipitation for the period 1960–1985, but they do show trend of warming by 0.7$^{o}$C (for the 15-year period) and some increase of precipitation in 1985–2000.

Changes in forest-tundra vegetation for the first period were investigated with topographic maps of 1:100 000 scale, which were made from air photos of 1961 and of 1:50 000 scale, made from air photos of 1984. Maps in digital format were transformed to a common scale and overlaid on screen for comparison. Vegetation plots which had changes (appearance or disappearance of forest and shrub) have been digitized.

Different scale of the maps, and therefore different degree of their generalization, required to make some corrections (e.g. filtration of small plots, <4 mm$^2$ in 1:100 000 scale, according with official instructions for map compiling). After correction we obtained the map of changes in forest and shrub distribution. It shows some changes in the character of forest-tundra transition zone – appearance of new small plots of shrub of tundra, 4 km$^2$ in total area; and, in opposite, disappearance of small plots of shrub, 3 km$^2$ in total area. But validation of these results by comparison with air photos of 1961 (1:50 000) and 1984 (1:30 000) for 5 control test sites has shown that in reality there were no changes in forests and shrub distribution for the first period.

For the second period 1985–2004, when the warming was noted, preliminary look through multitemporal images shows more changes for this time and promise more interesting results. As a possible changing detection method for the second period the comparison between airphotos 1961(1984) and Landsat ETM+ (from Google Earth) and ASTER images was created.

Various temporal differences were discovered in different parts of the territory.

– In the south-western test site, near the boundary between real forests and forest-tundra zone, where islands of forests breaks into forest-tundra zone, increase of forests area takes place due to thickening of shrubs.

– In the eastern test site with typical lichen tundra, at elevated part of the territory, there are practically no changes. But in the north-eastern test site, in the lowest part of the tundra zone, decrease of lichen area took place, mainly at river terraces.

– In the south test site, inside the forest-tundra zone, thickening of shrub and draft-shrub vegetation is seen in some places.

In summary we observe a northward shift, in places, of the northern forest line and southern tundra line, as well as changes in the character of the forest-tundra transition zone, mainly thickening of shrub vegetation, for the period of warming during 1985-2000.

## Plant-induced variability in soil nutritional status in the forest–tundra ecotone in Khibiny Mountains

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Building on the concept of plants as ecosystem engineers, it has been suggested that soil can be considered a part of the extended phenotype of a plant. The effects of plant species on soil acidity and nutrient status vary according to the different processes involved, e.g. nutrient uptake, chemical weathering of the parent material, nutrient inputs in litterfall, and, in case with tree plants, in stemflow and canopy throughfall etc.

The advancing forest will alter element cycles because of different rates of decomposition and mineralization of the organic matter in forest and tundra soil resulting from differences in functions of key plants as ecosystem engineers. Indirect climate change effects through expansion of forest plants can be larger than direct effects on soil. Advancing tree line can, probably, increase nutrient availability.

This work is aimed at study of plant-induced variability in soil nutritional status in the forest –tundra ecotone in Khibiny Mountains, Kola peninsula, Russia. The predominant soil types in the study areas are podzol and cambic podzol developing on unsorted till and on eluvium-deluvium of nepheline sienites.

Soil samples have been taken in Um'echorr and Tuliok sites in the west and east of Khibiny mountains in forest-tundra ecotones in the vicinity of 8 strips of 10 x 50 m for which field mapping has been carried at the scale of 1:20 for determination of contribution of different tesseras to vegetation-soil cover. For comparison, soil samples taken in Kuelporr (central Khibiny Mountains) have also been analyzed.

To understand the effects of plants on soil nutritional status we study the relationships between the vegetation and soil cover. The question arises about the elementary units of vegetation and soil cover for study of these relationships. Our works have demonstrated that the elementary units for the investigations of these relationships could be tessera (element of mosaics by Jenny, 1958). The borders of tessera could be identified by distribution of the predominant plant species. So, we sampled soil taking into account the key tesseras. In total 11 tesseras in Tuliok and 31 tesseras in Um'echorr were tested.

The soil acidity parameters, total and plant-available concentrations of nutrients, total carbon concentrations have been determined by traditional methods.

According to results of our studies in Tuliok and Um'echorr there are differences in the parameters of nutritional status of soil below the tree crowns and between the crowns, as well as of soil below different tree species and in different tesseras between the crowns. For instance, comparisons between forest tesseras showed that the concentrations of total C , N and bio-available Ca, were higher in the organic horizons, and the acidity lower, below the crowns of Norway spruce than those below Scots pine, as well as those in between-the-crown tesseras with lichens, green mosses and dwarf shrubs. Only the organic layer between -the-crown tesseras with tall herbs in Kuelporr had a comparable acidity, total N and bio-available Ca concentrations. These differences in the acidity were attributed to the high Ca

concentrations in the senescent needles of spruce and the dense, low canopies of spruce that reduces the leaching of base cations from the organic horizons. Different mechanisms were proposed for neutralization processes in the different organic horizons (L, F and H).
In transition zones between tundra and forest-tundra, and forest-tundra and forest of Um'echorr 'tree islands' also demonstrated specific features in soil nutritional status. As it was expected, in lichen tundra of Tuliok significant differences in soil nutritional status have been found between lichen tesseras and tesseras without any vegetation cover.
Comparisons of spruce forests with green mosses and dwarf shrubs in Um'echorr and Tuliok, and spruce forest with tall herbs in Kuelporr demonstrated significant differences in soil nutritional status.
According to our results and the approach we applied we can demonstrate effects of plants on soil nutritional status and make conclusions about changes in soil nutritional status through an upward expansion of forests due to climate change (warming or/and wetting effects). We can also use the observed effects to extrapolate information on soil nutritional status in the study region using vegetation maps derived from very high resolution satellite imagery.

## Climate-growth relationship in *Pinus sylvestris* along coast-inland gradients.

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The northern distribution limit of Scots pine, *Pinus sylvestris* is strongly affected by climate. Both height and diameter growth holds an innate log of past climate useful for assessing scenarios of future tree growth. In this study, we focus on climate-growth relationship for pine during recent time, i.e. last 10-15 years, along longitudinal and coast-inland gradients in Northern Norway and Kola Peninsula by analysing *i)* height-diameter growth relation among sites and between years; *ii)* relations between monthly climate data (temperature and precipitation from June the year prior to growth to August the year of growth) and height and diameter growth; and *iii)* how the growth response to these factors vary across west-east and coast-inland gradients. We used six open woodland study sites in the analyses, all located between the forest line and the treeline of pine, where pine saplings (i.e. <2m) were assessed for annual height growth (ruler measurement) and adult trees for diameter growth (two cores per tree with an increment borer). In total, 49-92 saplings and 23-31 trees were included in the analyses per site. Height and diameter growth relations within and between sites were examined with Pearson's correlation analyses. Climate-growth relationships were examined by the use of bootstrapped confidence intervals that estimates the significance of correlation coefficients by using standard procedures in the software program DendroClim 2002.
Two pronounced growth peaks of both height and diameter were identified, 1997-1998 and 2004. In 1996 and 2006, we found a decrease in growth at all sites. The main pattern for both height and diameter growth throughout the study sites is the influence by winter precipitation. In addition, July the year prior to growth show a significant positive relationship with height growth at all sites and diameter growth at the easternmost sites. An early start of the growth period is positive both for height and diameter growth: a positive

impact by precipitation and/or temperature is found at most of the sites, especially in May previous year and in May and June the year of growth.. Our results indicate that although temperature is the most growth-limiting factor, as in most northern areas, precipitation plays an important role in both height and diameter growth. We found no difference in the rate of influence of the two climatic factors between coastal and inland sites.

## Structure, dynamics, and regeneration capacity of the forest-tundra transition zone in N Norway and NW Russia.

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The overall aim of this PhD program is to through analyses of ecological factors controlling Scots Pine (*Pinus sylvestris*) distribution at the forest-tundra transition zone in Northern Norway and Kola Peninsula characterize past and ongoing changes in the region. A three dimensional approach reflecting regional differences in the major environmental driver, climate, was used when selecting the study sites across the study region: Atlantic vs. Arctic regions; coastal vs. inland; and altitude. In total six study areas with each three sites are used. Data collection at the sites follows the PPS Arctic Manual and included; site characteristics, canopy cover, stand structure, age structure, tree-, sapling- and seedling characteristics, and height- and diameter growth.
The PhD program is composed of five individual studies: 'Climate-growth relationships in *Pinus sylvestris* along coast-inland gradients'; 'Structural divergence in the arctic-boreal transition between different climate regions'; 'Conifer age structure variation along spatial and temporal scales in northern Norway and north-western Russia'; 'Tree recruitment capacity across the treeline zone: climate driven spatial and temporal variation'; and '50 years of treeline change in Khibiny Mountains'. The analyzed data from these studies show the following preliminary results: *1)* Height and diameter growth shows a strong correlation with winter precipitation and July temperatures. This points towards a positive effect by snow insulation during winter and/or spring moisture availability, combined with growth conditions during the summer. *2)* The leaf area index measured across the forest-tundra transition reveals denser vegetation in the central contra western and eastern sites, and at the inland contra coastal sites. Thus pointing towards a more abrupt forest-tundra transition in these locations, this could be due to a higher grazing pressure in those areas. *3)* Age structures for all study areas cover the time back to the 19$^{th}$ century but establishment/survival peaks vary among sites. At the western and central coastal sites, a clear establishment/survival peak is shown in the last 25 years. At the inland eastern sites, age classes are more evenly distributed over the last 40 years but with scattered older individuals. *4)* In the Khibiny Mountains (inland Kola Peninsula site), a 20-30 meter advance in birch treeline the last 50 years is found. This study also reveals winter precipitation as the main climate signal. Establishment and survival of seedlings at the uppermost fringe of the distribution limit is ensured due to snow cover during winter. Further analyses of these preliminary results are needed to fulfil the aim of the PhD program.

## Organization and visualization of spatial information for northern socially-oriented observations

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The questions which connected with formation and use of an infrastructure given socially-oriented observations are actual in many spheres of scientific activity. The data used at gathering and visualization of the information on socially-oriented observations is the result of interviewing, statistical data, databases, tables, schedules, maps, texts, photos, satellite images, audio records of respondents. All these types of information represent practical interest for researches and there is a necessity for correct structurization and the organization of all this data. It is needed to maintain a wide access to sets of details, and first of all to results of interviewing and the statistical data. All data file is represented in the form of a uniform model in which information input as well as processing and representation occur. This model is not definitive; it is more likely the certain base structure serving for primary ordering of the data used in researches. Using this model it is possible to structure the saved up data, and further to modify with reference to any territorial formation. The architecture and information structures of uniform system of the data are formed taking into account level of served users and their technical and program possibilities. Thus each of structures of the data, entering into the general integrated model and interconnected with other structures, is compared with corresponding section of the general model. Thus, realization of the stratified approach allows to form sets of the interconnected structures containing the references to the same primary data. At such methodological approach the primary goal - creation uniform information system of researches - is accompanied by formation of a superstructure, the top communicative level through which access is provided to information resources of the data. Service of the user of uniform information system is carried out as follows: at the first stage on demand the relevant information from a database is given to the user. At the second stage after the user will orient available the primary information necessary or its problems useful to the decision, the data which are in a uniform database or other databases of researches are given to the user. Updating of information system in all specialized bases of the spatial data will be carried out by means of replication mechanisms from uniform base which will be constantly supported in an actual condition. Cartographical services constructed on these principles will be the effective tool of visualization of the data. Thus through cartographical service it will be possible to receive any information without dependence in what file format it is presented in uniform information system. Tools of visualization of the data will be modern GIS and multimedia technologies which will be closely connected with data links – Internet.

## Change of the treeline ecotone in Khibiny Mountains, Kola Peninsula, over the last 50 years

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We present analysis of the treeline ecotone changes using aerial photos of 1958 and 1990, high-resolution satellite imagery of 2006/2008, in comparison with age structure data for two study sites in the Khibiny Mountains, Kola Peninsula and with regional temperature and precipitation data (for Murmansk meteorological station) since 1940.

The age structure data were collected in the field during summer 2008 at two separate sites of the Khibiny Mountains. At the birch site (Tuliok), one 20 metre and one 10 metre wide sample bands stretching from the treeline to 100 and 50, respectively, altitudinal metres above the treeline were used (350 m and 150 m long, respectively). Small birch individuals, <5cm in height, are difficult to locate and consequently most likely under-represented in the sample. In addition, 19 birch trees marking the local treeline were selected for age determination. At the pine site (Umechorr), the data was collected in sample plots at treeline and above the treeline. The treeline data were collected in three 50x50 meter adjacent sample plots, the data from above the treeline in eight 50x50 meter adjacent sample plots. All pine/birch individuals were cored for age determination at the base if the diameter of the stem was thicker than 3.5 cm, or otherwise cut at base.

Satellite and aerial image analysis consisted in identification of the highest points with growing trees (10 test sites of 10 trees each for Tuliok and 7 test sites of 10 trees for Umechorr), drawing the treelines and comparison of their altitude over the period of change. The following imagery was used: air photos of 14/08/1958 (spatial resolution ca 2 m) for both sites; QuickBird satellite image of 28/06/2006 (2.4-0.6 m) for Tuliok; air photos of 18/07/1999 (1 m) and WorldView satellite image of 29/07/2008 (0.5 m). Airphotos were orthorectified using DEMs created from 1958 (Tuliok) and 1999 (Umechorr) stereo airphotos, and satellite images were rectified to the orthophotos. Ground control points were taken from the 1:50000 topographic maps, thus seriously limiting the achievable accuracy, although additional local adjustments were made during change detection. While the relative height differences are quite accurate, the error in absolute treeline height determination is over 20 m.

Daily temperature and precipitation data from the meteorological station in Murmansk 140 km north of the study sites were adapted to monthly, annual and seasonal components. The temperature data show no trend during the last 70 years, while precipitation shows an increasing trend.

The age distribution at Tuliok reveals that most of the colonization by birch occurred after the 1960s with establishment peaks from mid-1980s. At Umechorr most of the colonization by pine occurred after 1950s and particularly in the 1970s and 1990s.

Treelines show consistent upward movement from 1958 to 1999 and to 2006/2008. At Tuliok the measured treeline advance (birch) is 29 m in the 48 years; at Umechorr (birch and pine) it is 27 meters in 50 years. The actual advance may be less, because the smallest trees identified in 2 m-resolution airphotos of 1958 are likely taller (up to 4 m) than the smallest

trees (2 m) identified in more recent imagery (0.5-1 m resolution). Additionally at Umechorr pine and birch treelines cannot be differentiated.

At Tuliok, there were no significant correlations between number of established individuals in each year and monthly, seasonal and annual average temperature, nor monthly, seasonal and annual total precipitation. At Umechorr, there was no correlation between the year of establishment and average temperatures. However, number of individuals established in the respective years significantly correlated with January and February precipitation, and the seasonal total precipitation of winter (December, January and February).

## The influence of an advancing shrubline on tundra soil temperature dynamics

**Isla H. Myers-Smith and David S. Hik**
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With a warming climate, arctic ecosystems will experience shifting boundaries such as the spread of tall shrubs into tundra communities. Rapid shrub expansion has been documented in arctic Alaska and north-western Canada using repeat aerial photography, and satellite imagery. Increasing shrubs could alter the soil thermal regime and reflectance of the tundra ecosystem. In the winter, snow trapping can insulate soils, and has been proposed as a positive feedback mechanism for promoting the expansion of shrubs in the arctic. Results from our experimental manipulations in the south-western Yukon indicated that, during the growing season, the shrub canopy shade the ground surface, and in winter, snow trapping insulates the soil. These data suggest that cooler summer soils will offset enhanced nutrient cycling from warmer winter conditions. The results from this field study, when synthesized with other work from around the arctic, can be used to estimate the influence of increasing tundra shrub cover to regional and global climate.

## Detection of forest-tundra ecotone properties in very high resolution satellite imagery through integration of image processing approaches

**Anton Novichikhin and Olga Tutubalina**
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Automated remotely-sensed (RS) image processing data provides a powerful tool for the study of forest vegetation. Very high spatial resolution (VHR) imagery (with resolution better than 1 m) opens new opportunities for mapping of forest vegetation at individual tree/shrub level. This is particularly valuable for mapping the forest-tundra ecotone. The objective of this study within the PPS Arctic project is to develop techniques for determining various parameters of the forest-tundra ecotone from VHR imagery, describing its condition and dynamics, such as: the number of trees per unit area, their height, crown area, changes of these over time.

The most popular methods of RS image analysis are global (per-pixel). In the images with very high spatial resolution, texture and spatial relationships between objects portrayed become important. This is addressed by the focal object-oriented analysis, which investigates the distribution of reflectance or class values of the image pixels within a "moving window", which may have some weight coefficients to reflect a model of the objects being searched for.

We have developed a method for automated processing of satellite images, based on a combination of global and focal image processing algorithms. It has been tested for the QuickBird image of 28 June 2006 for the Tuliok key site in Khibiny Mountains (2.4/0.6 m spatial resolution for multispectral/panchromatic imagery). Image processing was implemented in two successive processing models in i) ERDAS IMAGINE 9.3 and ii) ESRI ArcGIS 9.3 software. The method includes several stages:

1. Multispectral/panchromatic image fusion
2. Creation of a classified image showing Shadow/Vegetation/other classes (SV image), using threshold (parallelepiped) classification of the NDVI, IHS transform (from the fused image) and variance filter image (from the panchromatic image)
3. Focal analysis of the SV image using matrix models of trees with shadowed crowns, to detect trees and shrubs with specified crown size
4. Focal filtering of the intermediate images to remove excessively overlapping trees
5. Vectorisation of the detected trees and shrubs for further processing in a GIS package
6. Final filtration to remove small falsely identified trees
7. Validation of the identification of trees and shrubs.
8. Production of derivative maps: separation of trees and shrubs by height (using shape-from-shadow technique), calculation of distances between trees, drawing the forest boundary etc.

The SV-image creation and processing was based on the method described by Greenberg et al. (2009); however, the SV image was enhanced by using IHS transform of the fused image and a texture index (Variance) of the panchromatic image. High reliability of the results of automated interpretation has been confirmed on the basis of visual interpretation for a series of test plots.

The resulting maps of trees and shrubs enable to calculate the number of trees and large shrubs per unit area, with their division into several classes by crowns diameter, and to calculate the distance between trees. Terrain-and sun angle-corrected tree heights have been derived for trees in open areas (where the full shadow falls on land), with an accuracy of about $\pm 1$ m (given the image resolution of 0.6 m). These parameters enable to determine the position of the forest line, and of the tree line, to extrapolate the results of ground-based research in mapping forest vegetation. Delineation of the krummholz line is still problematic due to low heights and small sizes of individuals, although it will be found between the tree line and the mountain tundra belt whose upper limit can be derived from classified imagery.

Reference: 1.Greenberg J.A., Dobrowski S.Z., Vanderbilt V.C. 2009. Limitations on maximum tree density using hyperspatial remote sensing and environmental gradient analysis. Remote Sensing of Environment, 113: 94-101

## A biogeographical analysis of the distribution and colonisation of frost hollows along a latitudinal gradient in the boreal forest

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In boreal forest, trees are well adapted to harsh winter conditions. However, when freezing events occur during the growing season, trees can be damaged, particularly during bud break. In frost hollows, frost events are frequent and colonisation by trees limited. Frost hollows are small topographic depressions characterised by nocturnal frosts occurring every two or three days during the summer. Summer frosts reduce germination and growth, leaving the depressions almost treeless. As a result, an inverted tree-line is produced at the boundary of frost hollows and nearby forest stands. With decreasing elevation in the frost hollows, trees are developing stunted, bushy growth forms.

Radiative frosts occur when more energy is lost during the night then have been absorbed during the day. Particular site factors induced the formation of a frost hollow. Dry soil does not retain heat as well as a wet soil. Also, clear and calm nights facilitate the stratification of the air. Denser cold air masses can then go down in the depression while warm air is released. All around the frost hollow, the open structure of lichen-spruce stand allows circulation of air masses. Finally, the high albedo of the lichen carpet covering the surface of frost hollows prevents radiation retention. Post-fire tree regeneration begins normally outside the hollows, whereas it is delayed in the depression because of frequent night frosts. Any future seedling establishment probably depends on local weather conditions.

The objectives of this project is to study the abundance, distribution and tree colonisation of frost hollows along a latitudinal gradient in central Québec, between $70^{o}$ and $72^{o}$ W and $48^{o}$ and $58^{o}$ N. Regardless of latitude, all frost hollows are typically distributed in sites surrounded by woodlands (or open forests). Frost hollows tend to concentrate more in southern part of the boreal forest than in the northern part. Fifteen sites, distributed according to latitudes, have been sampled for dendrochronological analyses of black spruce trees located in hollows. Stem analyses have shown that elongation inside the depression is always significantly lower than the elongation of dominant trees outside the hollow. Also, irrespective of the date of fire and latitude, tree establishment below the tree-line only occurred during the last half of the $20^{th}$ century. Frost damage to trees and soils (thufurs) seem to be more important in southern most hollows. This could be explained by the longer growing season in the south of the gradient, resulting in a greater number of thaw-frost cycles during summer.

## Comparing two methods of extracting growth rates from slow growing populations of trees.

**Elisabeth Oakham, Karen Harper and Brian Starzomski**
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Characterizing the dynamics of long-lived populations such as trees and arctic plants is usually data intensive. Data sets covering long periods of time are often required in order to detect a clear signal of change in rates of growth, fecundity and mortality. In the face of a rapidly changing climate, developing simple statistical and analytical techniques that decrease the time and resource investment in data collection for demographic studies would increase our ability to monitor changes in slow growing populations. Two methods of measuring tree growth were compared for efficacy, precision and efficiency. Growth rates obtained from measuring the size and number of annual rings in tree cores were compared to those obtained from measuring tree diameters in successive years. Core data of *Picea mariana* (black spruce) in Churchill Manitoba were compared to diameter data taken in summer 2008 and summer 2002. Growth rates derived from both types of measurement in each tree population were compared using correlation analysis. results of these comparisons will allow us to determine if simpler, quicker methods of assessing tree populations are as comparably effective as more labour intensive methods.

## Northern Knowledge: Creating locally-relevant educational materials from community consultations and northern ecological studies

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Human-induced climate change is being held responsible for the expansion of new species into northern regions, as well as shifts in animal migration patterns and berry productivity. As the intensive research of the International Polar Year (IPY) draws to a close, there is a need to understand how to share important findings with northern communities. Furthermore, there is a need in northern schools for locally-informed, culturally-relevant, and pedagogically sound educational materials that meet the objectives of northern curriculum. Here we present work that aims to determine the most culturally appropriate and pedagogically suitable ways to disseminate key scientific findings to northern communities. The IPY-supported scientific research of PPS Arctic Canada will be the focus topic; this research network is comprised of ecologists studying the impacts of a changing climate on the forest-tundra transition, or treeline. Consultations will be held with northern scientists, residents and educators to determine key ecological research findings, traditional knowledge, and northern pedagogical approaches that will shape the form of the educational materials produced. From these consultations, educational materials will be developed that engage northern students with science and traditional knowledge about climate and vegetation change. Self-selected participants will be interviewed to assess and reflect on the consultation process and educational materials. Finally, the community

consultation process will be evaluated, and recommendations will be made to northern scientific networks interested in creating educational materials.

## Vegetation Dynamics on Alpine Summits in the Boreal Forest (Quebec, Canada)

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Fire is one of the main factors responsible for the spatial heterogeneity of the boreal forest. Burned forests are often unable to return to their initial state. This failure can be due to climate changes or to disturbances occurring during a short time span. This situation can cause canopy opening and even tundra formation if fire occurs on a mountain summit. The primary objective of this research is to survey the diversity of the flora on tundra summits according to latitude across the boreal biome (in central Quebec). The secondary objective is to evaluate the altitudinal position of the treeline according to latitude.
16 mountain summits covered by tundra vegetation have been selected along a transect from Charlevoix Highlands (47° N) to the Caniapiscau Highlands (54° N), all of them located at approximately 70°W. Plant species were recorded using the line-intercept method. The data have been used to calculate the Shannon Diversity Index. Six primary dependent variables have been used: Shannon Diversity Index, Shannon Evenness Index, total species number, bryophyte species number, lichen species number and vascular species number. Data were analyzed according to tundra area, elapsed time since the last fire and elapsed time since deforestation, latitude, treeline altitude, bare ground area, soil pH and soil texture.
Correlation matrix shows that among independent variables, latitude and treeline altitude are strongly correlated ($R^2$ = -0.94). This result is much predictable because latitude directly affects climate, thus treeline altitude. Simple linear regression indicates that latitude alone explains treeline altitude with a high degree of accuracy ($R^2$ = 0.90, $p < 0.0001$). Altitude was thus not used for analysis. Tundra area and latitude are shown to have a major influence on dependent variables. The value of the Shannon Diversity Index calculated for each site was predicted at 64% ($p < 0.001$) using only the tundra area variable. Total number of species is dependant of tundra area, bare ground area and soil pH ($R^2$ = 0.64, $p < 0.0001$) whereas the number of vascular species depends of tundra area, latitude and bare ground area ($R^2$ = 0.50, $p = 0.01$). The number of lichen species depends of tundra area and bare ground area ($R^2$ = 0.53, $p < 0.001$). No trend associated with the number of bryophyte species was found. Overall, tundra vegetation found on exposed summits seems to be mostly correlated with climate. Anticipated global warming could then have major impact on arctic and alpine ecosystems because of potential tree expansion.

## Remote Sensing of Human Impact on the Position and Structure of the Northern Treeline

**Ekaterina Shipigina and Gareth Rees**
*Scott Polar Research Institute, Cambridge, UK*

The position and structure of the northern treeline are of great importance for understanding interactions between land and atmosphere at the global scale, and for socioeconomic and ecological interactions at local and regional scales. High-latitude vegetation is responsive to global climate change, but is also sensitive to a number of local and regional human impacts, which can be severe in some locations. However, the relationship between human impact and possible environmental feedback from northern vegetation at the local level to a regional and global scale has not yet been studied widely or comprehensively. In this paper, we consider the most significant types of human impact on northern vegetation: industrial atmospheric pollution, mining extraction, urbanisation/infrastructure development, logging, grazing and fire. Methods based on satellite remote sensing allow the detection and monitoring of at least some of these impacts. Some phenomena, such as the physical absence of trees, can be identified visually very straightforwardly and in some cases, the process can be automated. We present examples of hotspots of human impact on the treeline region and discuss the scope for identifying and monitoring them using Landsat imagery

## The relationship between bird communities and vegetation across a treeline ecotone in the Mealy Mountains, Labrador, Canada

**Brian M. Starzomski[1] and Keith P. Lewis[2]**
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We examined the impact of elevation, as well as floristics and physiognomy of vegetation (Rotenberry's hypothesis) on bird communities in the Mealy Mountains, Labrador, Canada. Our findings suggest that elevation plays a strong role in structuring bird communities, and that Rotenberry's hypothesis that birds are influenced by vegetation structure at larger spatial scales (among habitat) and by composition at more local scales (within habitat) is largely true in this system. Given the strong impact of elevation on vegetation structure and bird communities, we note that for bird species whose near-southernmost populations are found in the Mealy Mountains, climate change is likely to have a strong negative effect as alpine tundra habitat is lost.
Further, forest-affined species are likely to benefit from the increased tree cover as treeline moves poleward and upward.

## Chemical composition of plants in forest –tundra ecotone in Khibiny Mountains

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The photosynthetic organs of plants are often used for foliar diagnostics of soil nutritional status. Leaves/needles are the component of litterfall, and they are of great importance in the soil organic horizon formation. As a result of combining effects of climate changes and disturbances, contribution of different plant species to soil nutritional status and biogeochemical cycles will change.

This study is aimed at characterising chemical composition of photosynthetic organs of dominant plants in forest-tundra ecotone in Khibiny Mountains.

The samples of photosynthetic organs of tree plants (*Picea obovata, Pinus sylvestris, Betula pubescens*), shrubs (*Betula nana*), dwarf shrubs (*Vaccinium vitis idaea, V. myrtillus, V.uligonosum, Empetrum hermaphroditum, Arctostaphylos uva-ursi*), herbs (*Geranium sylvaticum, Cicerbita alpina*), and lichens (*Cladonia stellaris, Flavocetraria nivalis*) have been taken in the vicinity of 5 strips of 10 x 50 m in Um'echorr for which field mapping has been carried at the scale of 1:20 for determination of contribution of different plant microgroups to vegetation cover. The samples were dried, grinded, digested in nitric acids. Concentrations of metals in plant material have been determined by AAS, P and S –by colorimetry, N- by Kjeldal method, C- by Tjurin method.

According to the concentrations of elements in photosynthetic organs, spruce could be considered as accumulator of Ca, pine - of Al, birch – P and Zn, bilberry - Mn, lichens- Al and Fe, herbs- N, P, K, and Mg. The differences in the composition of two species of lichens have been found: concentrations of Ca, Mg, K were significantly higher, and of Al and Fe were lower in *Flavocetraria nivalis*. Comparison of two species of birch has shown that concentrations of Ca, Mg, and K were higher in *Betula pubescens*. Both species of lichens and birch demonstrated elevated concentrations of Ni and Cu in forests, forest-tundra and tundra in Um'echorr. Higher levels of these heave metals are, probably, related to emissions from Severonikel smelter located in Monchegorsk.

Comparative assessment of samples taken in forests, transition zones between forest and tundra, and in tundra for many species has demonstrated that concentrations of nutrients Ca, Mg, P, Mn were higher in forests whereas concentration of K was higher in plants sampled in forest-tundra and tundra.

The changes in plant composition were rather correlated with bio-available than total concentrations of elements in the organic horizons of soil, except for K. The K variations could be related to variations in water contents in tissues of plants growing in forest, forest-tundra and tundra. Elevated concentrations of K in plants have also been found earlier in the areas subjected to air pollution.

## The dynamics of the northern forest lines (birch and pine) in northern Norway and Kola Peninsula (Russia) revealed by spectral unmixing of multitemporal satellite images in the period 1972 – 2007.

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In order to detect the dynamics of the northern forest lines of birch and pine in the Eurasian Circumboreal Forest-Tundra Transition Zone (northern Fennoscandia and Kola peninsula in Russia) in the period 1972-2007 we applied the "spectral unmixing" through Minimum Noise Fraction Transform (MNF) and Mixture Tuned Matched Filtering (MTMF.) on different imageries like Landsat and SPOT. MNF (essentially a two-tier PCA) reduces and separates an image into its most dimensional and non-noisy components. To perform this calculation, image statistics must first be calculated. Once the data is in a less noisy form, it can then be compared to end-members through MTMF processes to determine composition. End-members can be determined through identification by such methods as Pixel Purity Index, n-space analysis, comparing to field observations, or comparing to a spectral library. MTMF is useful because it allows for unmixing pixels that are not directly related to the collected end-members; other unmixing techniques require that the analyst account for all the possible end-members in a landscape. To be able to assess these changes, field measurements using methods like digital hemispherical photography were acquired to quantitatively estimate vegetation characteristics such as leaf area index (LAI) and canopy crown closure in the forest lines. Also, vegetation maps, digital aerial photographs and Corona-images were utilized in the analysis. Another advantage found with the "spectral unmixing method" was that we were able determine the percent composition of the end-members (e.g. density of trees in the forest line) within a single pixel. Preliminary results show that the forest line for birch has advanced up to 20-30 meters in altitude since 1980 in the border area between Norway and Sweden. The latitudinal forest line for birch has advanced less than 0.5 km in northern direction in the period 1972 to 2007 in the border areas between Norway and Russia.

## Integrated studies of forest-tundra ecotone sites in Kola Peninsula in 2008

**Olga Tutubalina[1], Elena Golubeva[1], Tatiana Vaschalova[1], Anatoly Krasnushkin[1], Valentina Kravtsova[1], Gareth Rees[2], Maria Golubeva[1], Anna Mikheeva[1], Ksenia Kozlova[1], Pavel Blumberg[1], Anton Novichikhin[1], Alexandra Loshkareva[1]**
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This poster will present an overview of the Moscow State University team field research in Kola Peninsula in summer 2008, including: the overall concept of research; selection and features of key sites; methods; results; and future research.

The key concept is the integration of remote sensing and ground approaches to achieve the tundra-taiga ecotone characterization within the PPS Arctic project. Ground research in general follows the PPS Arctic manual with addition of more detailed characterization of terrain forming processes on this ecotone in the mountains.

Selection of the key sites performed jointly with other teams was based on analysis of remotely-sensed imagery, maps and previous studies. The sites include: Umechorr, Khibiny Mts (mountain, continental, west-facing, nearly natural, pine forest); Tuliok, Khibiny Mts (mountain, continental, north-facing, nearly natural, spruce and birch forest); Monchegorsk, central Kola Peninsula (mountain, continental, various aspects, severely impacted, former tundra and spruce and pine forests); Kanentiavr, northern Kola Peninsula (plain, oceanic, mostly flat, spruce, mixed and birch forest).

Methods include geobotanical descriptions, geomorphological descriptions, profiling and mapping, geochemical analyses for pollutants, ground spectroradiometry, remote sensing-based change detection analysis in natural environments and for ecotone structure analysis; ground- and remote-sensing based change detection analysis in severely impacted environments. These merge with the work performed by other teams (e.g. detailed vegetation and soil mapping by CEPL and INEP, stand age structure and characterization by NINA).

In the poster we will present main results of the characterization of the present state of the key sites. Regarding the ecotone dynamics, we detect upward movement of the treeline in Tuliok and Umechorr sites (by 30 m since 1958); northward movement of the treeline in Kanentiavr since 1980s (spatial extent is not yet possible to measure), as well as occupation of hills lopes with less favourable aspects, with no significant trend (from maps and remotely-sensed imagery) in the 1960-1980s. In the Monchegorsk key site any positive natural influence on altitudinal treeline is severely offset by the Severonikel smelter impact. Some revegetation by birch in lowlands previously occupied (in 1940s) by spruce and pine forests is probably due to the reduction of smelter production and emissions.

## An approach for mapping micro-mosaic structure of plant cover through integrating field data and high resolution images of the forest –tundra ecotone in the Kola Peninsula

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This study is aimed at characterising spatial structure and diversity of forest-tundra ecotone ecosystems, for small areas through field mapping of vegetation microgroups and subsequently for larger areas using very high resolution (VHR) satellite imagery.

Detailed field mapping has been carried out for 13 strips of 10 x 50 m at the scale of 1:20 in three key sites: Umechorr (centre lat, lon 33.246 E, 67.705 N) and Tuliok (33.790 E, 67.704

N) in Khibiny mountains in central Kola Peninsula and Kanentiavr to the east and west of Lake Kanentiavr (34.169 N, 68.870 E) in northern Kola Peninsula, Russia. The strips were georeferenced with a hand-held GPS with positioning accuracy of about 10 m. For the ground mapping, these strips were marked with a 1 x 1 m grid (using measure tapes and marking tape), and then microgroups were drawn by hand on millimetre paper. Boundaries of the microgroups were defined by distribution of the predominant plants.

The available VHR satellite images include panchromatic and multispectral QuickBird image of 28 June 2006 for Tuliok site and panchromatic Worldview image of 29 July 2008 for Umechorr. No VHR imagery has been obtained yet for the Kanentiavr site. So far, only the imagery for the Tuliok site has been analysed (where three ground strips have been mapped), because multispectral information proved essential for vegetation identification. The following five basic vegetation/surface groups can be readily distinguished in QuickBird imagery within the ecotone: trees; shrubs; dwarf shrub tundra; lichen tundra; non-vegetated areas. Trees and shrubs are mapped using both spectral and textural information and distinguished by height (below or above 2 m) using shape-from-shadow method. All other classes are mapped on the basis of spectral information.

The preliminary results are as follows:

1. At present only general comparison of ground vs. satellite-image derived maps is possible, with geolocation error of about 20 m. This is due to insufficient accuracy of hand-held GPS receivers and the absence of adequately detailed digital elevation models and topographic maps for the Tuliok site, which hinders accurate geolocation and orthocorrection of the Quickbird image. Therefore, 100x100 m image areas around the ground strips are analysed.

2. About 50 vegetation microgroups have been identified and mapped in the forest-tundra ecotone. The calculation of microgroup areas on the ground is in progress. Areas are also being calculated for classified imagery subsets for 100x100 m plots around the mapped strips. It is planned to assess structural diversity of ground and image areas using Shannon index. The comparison of ground and image-derived statistics will be used to characterise position of ground strips in the landscape and extrapolate structural parameters and information on soil nutritional status

Further plans for the 2009 include pre-selection of new ground plots at treeline and above up to the lichen tundra belt. Ground mapping for 1-2 locations in Tuliok (with up to 3 sub-areas each) will be carried out using a generalised legend to match satellite image-derived classes. Individual trees and other landmarks as well as corners of the sub-areas will be located with differential GPS receivers. A procedure for Quickbird image orthocorrection will be developed. Ground spectroradiometry data will be utilised to improve the accuracy of image-based vegetation classification. Finally, ground mapping data will be extrapolated through image classification to characterise structural diversity of the territory.

## Migratory caribou activity in the vicinity of the hydroelectric reservoirs of La Grande Complex, James Bay, Subarctic Quebec

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Nowadays, ungulate migrations are becoming more and more vulnerable to the disturbances caused by anthropogenic activities. Among the factors affecting these migrations, anthropogenic barriers (fences, roads, railways, etc) and habitat loss appear to be of particular importance. As such, the development of the hydroelectric potential in subarctic Québec during the 1970s might have interfered with the activity of migrating caribous. One of the main hydroelectric complexes (La Grande) is located in the southern portion of their present range. The objective of this study is to infer caribou activity in the La Grande region to assess the impact of the hydroelectric installations on caribou activity. To do so, we used a dendroecological approach that allowed us to infer caribou activity before, during and after the set-up of hydroelectric infrastructures.

## Eco-climatological factors limiting Peoples' Quality of Life in the Russian North

**Vera Vinogradova**
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The nature-climatologic discomfort index characterizes unfavorable nature conditions influencing peoples' quality of life. This index is determined by complex geographical factors and conditions - orographic, soil, botanic, climatic, hydrological, etc. and overall convenience of a territory for human's life.

In Russia eco-climatologic discomfort is associated mainly with the Northern including Arctic regions which occupy essential part of the Russian territory. There is a latitude increase of unfavorable (discomfort) nature-climatologic, social-economic, medical-biologic conditions for human life. Indicators limiting human life in the North (so called threshold northern indexes) need to be determined, estimated and need special systematization.

Among a great number of nature-climatologic factors of discomfort used to determine boarders of northern territories the main are:

Duration of the polar day (night), period with deficiency UV radiation during the year, sum of negative air temperature (°C), duration of the period with the air temperature below –30°C, duration of the frost-free period, duration of the period with the air temperature below +5°C, location of permafrost, thick-ness of seasonally melt ground, vegetation index, Bodman index of dry cooling power.

The map with isolines of nature-climatologic factors of discomfort has been made and will be presented. The boundary of the North is the general line combining all of these threshold isolines. This general boundary can be used as the nature-climatologic boundary of the North.

Absolutely and very discomfortable zones include arctic, tundra, forest-tundra and north boreal forest landscapes. Discomfortable zone include the most part of middle boreal forest landscapes in the European part of Russia and middle boreal and mountain forest landscapes in the Asiatic part of Russia.

## Socially-oriented observations in coupled human-nature system investigations in the Russian North within IPY PPS Arctic

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Socially-oriented observations (SOO) of Quality of Life (QL) have been carried out in the Russian North according to the methodology and Canadian-Russian collaborative Protocol which has been prepared by Institute of Geography, Russian Academy of Sciences and Carleton University, Canada within PPS Arctic IPY N 151 and included in PPS Arctic Manual edited by Annika Hofgaard and Gareth Rees. SOO have started to be carried in regions of Northern socially-oriented observation network including sites situated in very different bioms (from tundra to southern taiga zone) and various administrative region: The Kolguev Island, Nenets Autonomous District, Arkhangelsk Oblast (tundra); Kola penincular, Murmansk oblast (tundra, lesotundra and northern taiga) as well as Ustiansky district, Arkhangelsk Oblast (transition from middle taiga zone to southern taiga). Main approaches and principles of SOO indicated in the Protocol include involvement of broad groups of local and indigenous people; identification of limits (issues) and targets for QL improvement which helps to distinguish main indicators of SOO for different sites. For specially recognized main issues and goals, key indicators to be observed based both on people's perceptions and statistics have been identified.
Results of SOO based on interviewing and information-educational workshops, statistics, government reports, literature, etc. show that: 1.People's QL (well-being, health, human resources and capacities, etc.) is the major drivving force effecting the natural environment in the Northern regions (especially in the more populated Northern regions of the Russian Federation). Changes in climate and its consequences to the environment are important factors, but in relation to the future of settlements, communities and cultures, in the end it is the people of the North and their QL that are decisive. People's QL directly influences (as well as responses to) the state of natural environment, including northern forests and tundra ecosystems in the Russian North which is well-illustrated in observation sites. In some sites uncontrolled clear-cutting, Illegal logging and tourism had greater impact on forest degradation, even more than air pollution; 2. In addition to science and remote sensing, local people including indigenous are unique observers and appraisers of changes happening in the nature and society. Main issues and indicators for further observations identified for Murmansk Oblast, although their rank differs in specific sites of observations are: material well-being (wages) and level of its differentiation among the poorest and the most reach groups of the society; life expectancy and child mortality; quality of health-care system; state of the natural environmental; level of peoples' participation in decision making; quality of education; quality of socio-cultural service,

etc. 3.The interdisciplinary approach in SOO based on the five-sphere Concept of the structural organization of human-nature system is very perspective nowadays. According to this Concept in order *to achieve the main target - the QL improvement*, it is necessary to adapt and implement *the development strategies for sound solution of appearing **issues** of QL and strategic **goals** set for its enhancement* in interrelated spheres – social, economic, nature-environmental, management as well as the spiritual-cultural. One example of such a coupled approach to human-nature system development is the enforcement of the adaptation strategy for sustainable forestry management (recultivation, planting and protection) especially in regions where natural afforestation occurs due to climate change. In years of the world socio-economic crises, where many industrial enterprises are closing and people are losing their work, such strategies will give employment to people who have lost their previous jobs from one side, and from another it will increase the overall forested area and will follow important requirements of sustainable use of forests becoming important for the access of the Russian timber to the West-European markets, sensitive to environmental abuses and will provide important resources for recreation and tourism development as well. Forest area increase will also act as a mitigation measure to combat world climate change consequences. 4. It is not surprising, that some changes in Kola peninsular evident for scientists, such as forested area or treeline changes are not registered by respondents or ranked high as limits or opportunities for their QL. This is a result of the lack of sufficient environmental education and awareness among the local people and also of their greater concern with the low level of material well-being. SOO including both scientists and local observers will help to raise people's awareness of many coupled human-nature issues and opportunities of QL improvement in the North.

## 2000 – 2008 MODIS Land Surface Temperature evaluation for the Kluane region of the Southwest Yukon, Canada

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Since March 2000, the MODIS Terra satellite has produced daily Land Surface Temperatures (LST) at 1km grid cells using a physically based algorithm. MODIS LST provides higher spatial resolution than currently available statistical-spatial modeled data sets, especially at higher latitudes where environment monitoring stations are few and unevenly distributed. Initial results for the 2000 – 2008 period presented here include air temperature and LST. These relationships are well correlated for the four Environment Canada Monitoring stations within the study area and seasonal mean LST time series analysis showing spatial trends of statistically significant changes. Further research will integrate the high temporal resolution of spatially discrete sampling stations with the high spatial resolution of MODIS products (LST, NDVI, fractional snow cover) to produce a robust product with which to analyse arctic landscape dynamics.

## Snowiness changes in the Khibiny Mountains due to predicted global warming

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Snowiness is one of the indicators of climatic changes. In light of the predicted global warming the question of regional investigations of meteorological and glaciological indicators came up. For the last 25 years at Khibiny Educational and Scientific Base of Faculty of Geography, M.V. Lomonosov State University regular observations on snow cover, avalanche activity and meteorological conditions are being carried out.

General properties of snowpack in the test area of Khibiny base for 25 years are stable. The length of the snow cover period, dates of stable snow cover formation, average snow mass growth, values of maximum snow accumulation have interannual fluctuations but no significant trend. Investigations of snow cover stratigraphy also determine the absence of changes both in metamorphism processes, and in distribution of temperature and density in the snowpack layers.

The meteorological observations show a slight tendency for increase of the overall winter period temperature (by 0.28ºC per 10 years). Slight increase of mean annual temperature is detected in the data of the Centre for Avalanche Protection of JSC “Apatit”. However, these trends are not statistically significant. It is possible that such tendencies are simply the evidence of variability of atmospheric circulation processes.

Through comparison of data on winter types by snowiness and temperature conditions we have determined that around the test area of Khibiny base winters of mean snowiness and moderate temperature dominate. Snowy warm winters and not snowy cold winters are uncommon.

Since the 1950s avalanche activity in Khibiny Mountains varies greatly through time. At present the intensity of avalanche processes is at its maximum. There is a reduction of avalanche volumes simultaneously with the increase of their number.

We conclude from multiyear observations of the snowpack that changes of temperature conditions in the Khibiny test area are not significant and snowiness is stable in spite of the predicted global warming.

## Using information from geoportals for mapping and monitoring of the northern forest-tundra boundary

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The interface between the boreal forest and the arctic tundra is the Earth’s largest vegetation transition zone. This interface zone is over 13,000 km long and may be several 100 km wide, and hence occupies around 5% of the vegetated surface of the Northern Hemisphere. It plays a key role in the global climate system. The only way to map and

monitor such an extensive and often inaccessible area is the use of satellite remote sensing. Since the area is so large we have to use data with coarse and medium spatial resolution data from the sensor MODIS on the Terra and Aqua satellites and data from the TM/ETM+ sensors on the Landsat satellites. One of the most important features to detect is the *northern forest line* and this line is defined as the limit at which forest canopy closure ceases and the distance between single trees (height > 3 m) exceed 30 metres. Several methods (classification, spectral unmixing methods etc.) can be used to detect the forest line and in order to assess the quality of the detection we have to used ground based knowledge ("ground truth") such as tree height, tree density and tree species and vegetation type information gathered during intensive field and/or airborne (remote sensing) campaigns. In the often inaccessible areas of Siberia and Canada, it is mostly unfeasible or too expensive to obtain aerial photographs to carry out ground validation campaigns. The problems with obtaining validation data for detection and monitoring of the forest line can be solved by using information from various geoportals such as Google Earth, where the initial and basic information includes high resolution remote sensing data, and large-scale topographic maps. However, when obtaining information from these geoportals given restrictions have to be considered: high resolution remote sensing data with restricted user licenses (e.g. Quickbird, Ikonos or aerial photographs); the client's needs; and the methodology of using the information.

A comparative analysis of the opportunities offered by different geoportals is presented. In addition, the methodology of using geoportals as an alternative for ground based surveys and validation of remote sensing based analysis of the forest-tundra i zone or regions with difficult access is presented. The kernel of this methodology lies in the opportunity to use satellite images of high spatial resolution for detection of morphometric and qualitative characteristics of vegetation cover that are necessary for visual/automated decoding of medium to coarse spatial resolution satellite imageries or validation of map products based on such data.

## Northern forest line through time – from ancient maps to satellite images

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The Earth's largest vegetation transition zone is the interface or boundary zone between the boreal forest and the arctic tundra. This boundary zone is over 13,000 km long and can be several 100 km wide, and occupies around 5% of the vegetated surface of the Northern Hemisphere. It plays a key role in the global climate system.

Recently, the development of remote sensing methods and other modern environmental survey methods have contributed to analyses of both changes in location and structure of the forest-tundra boundary zone and causes of recorded change. Maps from different time periods and sources are of great value in this context. Firstly, they may reflect changes in the spatial structure of the vegetation, secondly they allow for estimation of rate of change in the transition zone. The use of various thematic and topographic maps based on contemporary data, such as remotely-sensed data and field based survey data, is the

current basis for such analyses. However, surveys of historical maps may provide important long-term information.

In this paper, we have analysed a broad scale of accessible cartographic information of the northern forest line and taiga-tundra transition zone in Fennoscandia including Kola Peninsula since the 16th century.

Three historic and thematic mapping sources are used in the study:

- different thematic and topographic maps from the 16th to the 20th century
- modern topographic and thematic maps (e.g. vegetation map and forest maps)
- information from geoportals (e.g. high resolution remote sensing data and topographic maps)

Analysis of different cartographic information was done by using GIS technology. For ancient maps, the following main operations were carried out:

- transformation of all initial maps into the same integrated coordinate system
- digitisation of the forest line
- visualisation of the forest line and the taiga-tundra transition zone
- quantitative-qualitative analyses of the forest line boundary and the taiga-tundra transition zone on the different maps.

While retrieving information from different thematic maps, the focus was on the detection of the taiga-tundra zone in general since in most cases old and small-scale maps only reflect the transition zone from forest to tundra and not location of the forest line *per se*.

The main task when analysing topographic maps was assessment of the geometrical variation in mapping the forest line boundary in connection with the generalisation degree previously done in the different scales from 1: 50 000 - 1: 1 000 000.

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